Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **20 MAR 2010**	2. REPORT TYPE	3. DATES COVERED
4. TITLE AND SUBTITLE **Toward an Integrated System for Command and Control Net-Centric Web Services and SUstainment Application to Homland Security**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Marion Ceruti**		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **SSC Pacific,53560 Hull Street,San Diego,CA,92152-5001**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT
This paper describes the architecture and requirements of an integrated system that is needed to support the command-and-control requirements of the Department of Homeland Security during crisis prevention, disaster relief, and other critical operations. The architecture is based on emerging science and technology that has been under development in information management. Lessons learned in the implementation of decision-support systems for Chemical, Biological, Radiological and Nuclear defense, standards, spiral-systems integration and implementation, and web-service-centric computing, contribute to the architecture?s design. The theoretical underpinnings of such a system are represented using a formalistic approach called ?paradigm reuse.?

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**4**	

Toward an Integrated System for Command and Control Net-Centric Web Services and Sustainment: Application to Homeland Security

Kevin Adams, Sandi F. Lehan, Marion G. Ceruti, Senior Member, IEEE,
Stuart H. Rubin, Senior Member, IEEE, and Jeff Waters
Space and Naval Warfare Systems Center Pacific (SSC Pacific)
53360 Hull Street, San Diego, CA 92152-5001, USA
kevin.adams@navy.mil, sandi.lehan@navy.mil, marion.ceruti@navy.mil,
stuart.rubin@navy.mil, jeff.waters@navy.mil

Abstract

This paper describes the architecture and requirements of an integrated system that is needed to support the command-and-control requirements of the Department of Homeland Security during crisis prevention, disaster relief, and other critical operations. The architecture is based on emerging science and technology that has been under development in information management. Lessons learned in the implementation of decision-support systems for Chemical, Biological, Radiological and Nuclear defense, standards, spiral-systems integration and implementation, and web-service-centric computing, contribute to the architecture's design. The theoretical underpinnings of such a system are represented using a formalistic approach called "paradigm reuse."

Keywords: Command & Control (C^2); Decisions; Web Services; Paradigm Reuse; Integration

1. Introduction

This paper describes support for the Department of Homeland Security (DHS) through three integration-oriented imperatives of a functionally integrated, service-centric [7] system to improve interoperability, reduce cost, and provide additional capability to diverse user communities.

1) National standards related to National Incident Management System (NIMS) and National Response Framework (NRF):
    a. First responders
    b. Local governments and agencies
    c. Regional and federal agencies
2) Outreach centers for technology transfer:
    a. Geospatial systems and C^2
    b. Chemical, Biological, Radiological and Nuclear (CBRN) defense and explosives
    c. Human factors and maritime domain
3) Technology assistance for:
    a. Architecture and data management
    b. Testing and accreditation
    c. Information assurance
    d. Acquisition, sustainment, and training

2. Background

This paper responds to the imperatives but also is related to several other needs for pilot programs at the city, state, and regional level. The individual states and representative agencies will respond with policies regarding their emergency management responsibilities. However, the DHS Science and Technology (S&T) directorates must ensure that capabilities contain the content-relevant objectives described in [4]. These capabilities also must contribute to the overarching goal of realizing a national integrated mission space for the seamless sharing of secure and public data among users, applications, and platforms.

The goal of becoming platform or system agnostic for seamless interoperability through data sharing is the ultimate driver. However, full implementation requires necessary standards and governance development. (See, for example, [6]). This is the appropriate level of coordination for situational awareness, but capabilities to address decision support require certain models that could be extended to the user for enhancing coordination efforts across agencies and jurisdictions. The system-agnostic approach and the layering are necessary to provide cost-effective measures to align and integrate the information-systems and services of disparate agencies and communities.

The first imperative addresses an integrated-resource repository implementation and sustainment plan for supporting web services and components. Without effective coordination across the DHS community for supporting net-centric common services and components, each city, state, and region will duplicate efforts in building and maintaining common web-service hardware and software solutions. Duplication of effort will incur

IEEE IRI 2010, August 4-6, 2010, Las Vegas, Nevada, USA

unnecessary costs across the DHS community as well as result in development of non-interoperable, proprietary, and "stove-piped" web services and components. Integrated approaches to C^2 that avoid duplication of effort are described in [6].

The second and third imperative would be to define a mechanism to sustain the web services and components that will result from the successful implementation of [1] and [6]. Support through command-and-control technology transfer and reuse must upgrade continually the capability to manage emergencies and provide interoperability at low cost across multiple agencies. This also extends to ensuring interoperability between civilian and federal command-and-control efforts.

The Disaster-Management eGov initiative (DM) [3], improves access to disaster-assistance information, simplifies applying for disaster assistance, and eliminates redundant agency processes. The DM-initiative elements improve information sharing, reuse, and enhanced services for citizens and the emergency-management community, including first responders at the local, tribal, state, and federal levels. DM aims to meet the nation's need for a unified and integrated point of access to disaster preparedness, mitigation, response, and recovery information. DM includes Disaster Management Interoperability Services (DMIS) and Open Platform for Emergency Networks (OPEN).

Through the DisasterHelp.gov portal, DM provides a unified point of access to disaster-related information and services for citizens and emergency organizations. The portal is a centralized location for the public and for first responders to access disaster information and services provided by government agencies and non-governmental organizations, thereby reducing the performance gap for a single federal disaster-management site. DMIS provides government and non-governmental organizations secure disaster-information exchange. The DM Standards Initiative [4] facilitates the development of emergency data-exchange language standards for incident management enabling the emergency response community to share data seamlessly and securely across disparate information systems. (See, for example [1] and [6].)

3. Requirements

DHS and Department of Defense (DoD) web services and net-centric implementation requirements include the following.

- Service-Oriented Architecture (SOA) open architecture-compliant C2 system interfaces [7].
- Migration to a web-services environment to integrate common services and components for disparate users at various echelons and agencies.
- Promotion of information-technology system interoperability with multiple agencies of differing size and complexities [1], [6].
- Implementation of DHS and DoD net-centric web-services vision by reviewing prevalent government-agency architectures, capability needs, and mandated standards to identify commonalities, synergies, conflicts, gaps, and potential improvements [6],[7].
- Examination of net-centric standards, guidance, and implementation documents developed across the DoD and their condensation into a clear and concise form that users and developers would find useful in developing common services for a web-services environment [6], [7].

An interfacing model needs to be adopted to meet requirements in data management [1], common-component software and hardware interfaces, and the sustainment of a command-and-control components repository with linkages to existing user-specific repositories and artifacts.

The main requirements are to coordinate implementation of web-service policy across the greater DHS domain, capture assistance requests from users, and establish a support and sustainment capability for the emergency management.

DHS S&T has established activities that could be leveraged to meet interoperability standards requirements, including the Integrated CBRN (ICBRNE) testbed, Homeland Security S&T testbed (HSSTT). ICBRNE is focused on data models, data integration, data interoperability and sensor standards. (See, for example [2] and [6].) HSSTT is focused on interoperability testing. Extensions to various agencies through the SSC Pacific End-to-End C^2 test bed leverage connections across multiple domains and agencies.

The DHS S&T is chartering a Technology Assistance Center (TAC) that would provide a cost-effective single point of contact for users (customers, developers, and emergency managers) to receive professional and timely assistance with Information Technology (IT) and net-centric component standards, interoperability, and supportability needs. The TAC's ultimate goal is to facilitate the creation of more efficient, common, and consistently superior interoperable and integrated IT systems across the DHS S&T community.

Lessons learned in interoperability and integration provide that, as well as C^2 technology development to provide decision-support upgrades to support the C^2 domain's transition to web Services. (See, for example [1], [2], [6], and [7].) Lessons learned also will be used in a technology-assistance center that supports technology transition, architecture development, data fusion and correlation, training, requirements generation, testing, and standards development for the CBRN community.

The TAC executes Fiscal-Year (FY) responsibilities based on directives from the DHS S&T stakeholders. This direction is aligned to current FY requirements in the implementation of DHS policy as promulgated by each of the Directorates. The DHS S&T TAC operating in a continuous support capability could provide the necessary guidance to the DHS users for the transition of IT systems to disparate environments 24 hours a day, seven days a week. The TAC focuses on the coordination and education of the community regarding the proper direction and the support in meeting DHS S&T IT net-centric policy and standards.

The TAC cannot sustain the component net-centric services components required to match the various SOA strategies set forth by each user echelon. However, it could enable consistent implementation for data fusion and correlation for national emergencies and events. A formalistic approach is needed to generalize information sharing and reuse, and to promote paradigm consistency and reliability among diverse first responders.

4. Paradigm Reuse

A formalistic, efficiently extensible approach for sharing and reusing knowledge is needed across the C^2 enterprise domain. This requirement rules out traditional expert systems. Moreover, the integrated system needs to have the capability to fuse disparate domains for true knowledge sharing. Because knowledge is inherently incomplete, users will want a creative paradigm that can induce some degree of knowledge. Whereas this does not represent a radical departure, at least it can extend the saved knowledge using common-sense reasoning.

The first task in developing any formal system for the capture and reuse of knowledge is to solve the problem of how to represent that knowledge. Hofstadter has written, "Proximity to a concept and a gentle shove are often all that is needed for a major discovery and that is the reason for the drive towards languages of ever-higher levels" [5]. Our formalism must:

- Be close to natural language or readily translated into it;
- Support generalization and abstraction;
- Support sequential and parallel operations;
- Enable the formation of reusable and extensible schemata;
- Underpin a case-based reasoning system (CBR).

One existing formalism that comes closest to satisfying these constraints is predicate calculus. However, experience has shown that predicate calculus is difficult to put in bijective correspondence with natural languages. Predicate calculus has a superfluous mechanics for reasoning. However, the CBR system also will cover that aspect.

The following formalism draws from CBR to define the knowledge base, and typogenetics to abbreviate the cases. Thus, the paradigm-reuse formalism is developed below using an example.

1. The system shell consists of a case-based reasoner defined as $s_{i,j} \rightarrow a_{k,l}$, for i,k = 1, …, m; j,l = 1, …, n. This defines the knowledge base, where the inference engine assigns the $a_{k,l}$ a metric. The inference engine then selects the $a_{k,l}$ based on the metric's ranking. Ties are broken in favor of the most recently acquired or fired case, which is similar in procedure to hill-climbing algorithms. The metric needs to exceed some defined threshold, δ , or no match is said to exist.
2. For example, consider the screening of airport passengers. The first task is to abstract this natural-language description into general predicates. Thus, if (screen (passengers)) then proceed (gate) else proceed (detention). This creates three maps and one situation-action rule that are saved in the same case base as follows. Grammatical changes are realized by code to generalize applicability.
   a. screen airport passengers → (screen (passengers))
   b. proceed to gate → proceed (gate)
   c. proceed to detention → proceed (detention)
   d. The three-step sequence of events can be summarized as "iatbec," which is an abbreviation of the rule, "If (a) then (b) else (c)."
   e. In keeping with JAVA programmer's notation, "or" is written as "||" e.g. "A||B." → Permit parallel processing where pertinent, available and included.
   f. Similarly, "and" is written as "&&" e.g. "A&&B." → "A and B" data aggregation, integration or fusion
3. Next, generalize the results of the previous step. This schema must be randomized to maximize its reusability. Generalization takes the form of knowledge fusion.
4. Suppose that the knowledge base also contained the knowledge, "If (identity = (pilot in command)) then proceed (gate) else (screen (passengers))," as a distinct case, abbreviated as "iptbea." Here "bea" "means (b) else (a)" like in paragraph 2d. Here, "p" designates pilot in command and the other letters, "i__tbea" are the defined in paragraph 2. The fusion of iatbec with iptbea is a typical typogenetic problem and yields, ia||ptbea. The fused rule indicates that the would-be pilot would be screened as a passenger and would not be detained (rule c), which would be the case if the fused rule were, ia||ptbec. In either case, the fused rule allows the pilot and a passenger to be screened in parallel, which is why the "||" sign appears in these rules above. As in the case of iatbec, this map is saved in the case base and is itself subject to further generalization

with other cases, where appropriate. For example, f expresses the fusion of the 2 cases described above:

f. iatbec && iptbea → ia||ptbec||a

5. Cases described above automate the difficult process of iterative generalization for knowledge fusion. They are traceable and the trained user can delete or update them as necessary.
6. Next, the fusion of knowledge may have produced incorrect rules, depending on the implementation domain. If imperfection is allowed, the system can do far more, albeit at the risk of error. For example, suppose that the plane's first officer or co-pilot (o) approaches the gate. Also, suppose that the system does not have an overriding explicit case or case generalization to cover this situation. The system would note that, and reason out the following suggestion by way of abstraction. Abstractions are saved in the form of sets in the same way that declarations are saved in a programming language. Abstractions are saved separately from cases but they are capable of evolutionary modification just the same. Rule (g) tells the reasoner to treat a first officer as it would a pilot in command by placing them in the same set for business rules and reasoning.

   g. {o, p}

   By substitution from (g), we obtain the generalization, ia||ptbec||a → ia||otbec||a, which suggests that identified first officers may proceed to the gate, or otherwise be detained or screened as a passenger. TSA officials would disagree with this result, in which case the set in (g) would be broken, or the rule in (f) would be expunged, depending on the nature of the user's disagreement. Such disagreements and resulting deletions may occur at any time. Given that this is the case, the correct knowledge must be captured by a case, as expressed in (h).

   h. ia||ptbec||a → ia||otbec||a

   Incorrect and unattractive cases will fall into disuse because all cases and sets are maintained by expunging the least-frequently used member whenever space becomes at a premium (or even when it is not, depending on the circumstances). In some systems, instead of expunging, such members are written to an optical jukebox or its equivalent. Cases deemed to be correct and logical, as determined by their frequent usage, are moved to the head of their respective list.
7. Cases are ranked by using a simple predicate matching and counting scheme. All predicates are given the same uniform weighting.
8. Higher-order transformation rules should not be incorporated as the possibility of correct action drops off rapidly, for most domains, with successive levels of generalization. Such rules map the mapping rules and will not be discussed further. Indeed, for random domains that lack any meaningful content, even one level of mapping rules, as presented above, will not work efficiently. However, the material in this section is predicated on the low likelihood of observing such a domain, and an information source to be exploited is thus identified.

The presented model for paradigm reuse will be modified through implementation. No single model is perfect for all applications. Rather, the commonality of knowledge and its representations remain to be exploited more fully. This formalism is particularly applicable to DHS problems because:

- It reuses knowledge from multiple sources across domains to solve problems in a given domain.
- It is a machine-learning paradigm that acquires generalized knowledge across domains.
- First responders can train and query the system using structured English, and they can train the system rapidly.
- The resulting C^2 system essentially supports DHS operations through knowledge fusion.
- Over time, for a relatively fixed domain, the error rate converges towards zero.

Acknowledgments

We thank the Department of Homeland Security and SSC Pacific's Business-Development Board for support. This paper is the work of U.S. Government employees performed in the course of employment and no copyright subsists therein.

References

[1] M.G. Ceruti, "Data Management Challenges and Development for Military Information Systems," *IEEE Transactions on Knowledge and Data Engineering*, Vol. 15 No. 5, pp. 1059-1068, 2003.

[2] M.G. Ceruti, and M.N. Kamel, "Preprocessing and Integration of Data from Multiple Sources for Knowledge Discovery," in a special issue of *International Journal on Artificial Intelligence Tools, (IJAIT)*, Vol. 8 No. 2, pp. 152-177, June 1999.

[3] DHS Exhibit 300 Public release BY10/FEMA – Disaster management E-Gov Initiative 7 Jan. 2004.

[4] DHS Management Directive 10100.1 Organization of the office of the Under Secretary for Science and Technology, 21 June 2007.

[5] D.R. Hofstadter, *Gödel, Esher, & Bach: An Eternal Golden Braid*, New York: Basic Books Inc. 1978.

[6] J. Waters, B. J. Powers and M.G. Ceruti, "Global Interoperability Using Semantics, Standards, Science & Technology (GIS3T)," *J. Computer Stand. & Interfaces.* Vol. 31 No. 6, pp. 1158–1166, 2009.

[7] D.R. Wilcox and M.G. Ceruti, "A Structured Service-Centric Approach for the Integration of Command and Control Components," *Proc. IEEE International Conference on Service Computing (SCC 2008)*, Vol. 2, pp. 5-12, July 2008.